Food and feeding habits in a population of common spadefoot toads (*Pelobates fuscus*) from an island in the lower Danube floodplain

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Analysis of the food of a population of *Pelobates fuscus* inhabiting an island in the lower Danube floodplain revealed high prey diversity. Most of the animals studied were juveniles and subadults because they represent the largest part of the population. The high percentage of empty stomachs (38 %) suggests that feeding is variable in time. Most of the prey items consumed (75 %) were small, with a body length from 2 to 6 mm. A significant positive correlation was found between toad body length and prey length. Significant positive correlations were also found between toad body length and the average, maximum, and minimum prey sizes. Insects represented more than half (58.8 %) of the prey categories consumed. The dominant groups of prey taxa were snails (Gastropoda, Pulmonata), ants (Hymenoptera, family Formicidae), and beetles (Coleoptera). These three taxa represent half (50.6 %) of the prey categories consumed, with the rest of the taxa representing less than 10 % each.

Prey abundance in the environment and diversity of prey consumed were positively correlated. There was a positive correlation between the relative abundance in the environment and the frequency of occurrence. Two preference indices (Manly's Alpha Index and Ivlev's) were tested, but both were of limited value in discriminating between prey categories preferred or avoided. The present data suggest that *Pelobates fuscus* is a generalist feeder with a broad trophic niche.

Introduction

The common spadefoot toad, *Pelobates fuscus*, is a strictly nocturnal, burrowing species. Despite being distributed over most of Europe (Arnold & Burton, 1992), little is known about its feeding habits and food preferences (Medvedev, 1974; Sczerbak & Sczerban, 1980; Nöllert, 1984). It is not yet known if *Pelobates fuscus* is a generalist or a specialist feeder, and if it is a sit-and-wait or an active foraging predator.

During a study on the dynamics of the amphibian communities of an island in the lower Danube floodplain, data were gathered to allow a detailed analysis of feeding habits and food choice of *Pelobates fuscus*. Data on the availability and diversity of litter invertebrates were also available.

Materials and methods

Study area

The study site is the island of Chiriloaia, situated south of the town of Brăila (fig. 1). The island is flat (less then 1 m above sea-level), and is 9 km long by 4 km wide. Several large, shallow lakes exist in the interior of the island. The vegetation cover is extremely dense and diverse, ranging from reeds (*Phragmites* sp.) and cattails (*Typha* sp.) near the lakes and channels, to natural willow tree forests and willow and poplar tree plantations. Old willow trees provide shelter and large amounts of wood debris. Clearcuts and pastures represent less than 10 % of the island's area.

Life on the island is controlled by the periodic floods of the Danube, as suggested by the flood-pulse concept (Bayley, 1995). During the spring floods water levels rise more than 4 m. At times of high waters, the entire island is submerged. Most of the animals survive these often prolonged periods of flooding by seeking refuge on the large amounts of floating debris and on large, old willow trees.

Sampling program

During 1994 and 1995, 70 one- and two-liter pitfall traps were used in the field. Sampling started in July 1994, when the water level began to decrease after the spring flood. The traps were filled with 40 % ethylene glycol and were emptied twice a month. During the high water levels in the spring of 1995, some of the traps were flooded and the captured animals lost. Aside from invertebrates and other amphibians, 162 juvenile and subadult *Pelobates fuscus* were captured in these traps, primarily during their migrations (Cogălniceanu et al., 1997). Eight adults (seven males and one female) and 20 juveniles were captured at night during torch surveys. In total, 190 spadefoot toads were captured, measured to the nearest 0.1 mm with dial calipers, and their stomach contents were preserved in 70 % alcohol for identification. Prey items were classified by taxon (to family when possible) and life stage, and their length was measured to the nearest 0.1 mm using a binocular microscope. The invertebrates captured in the pitfall traps were also counted and identified.

Data analysis

The relative abundance of the various prey categories was estimated from the stomach content analysis. The frequency of occurrence was determined by dividing the number of stomachs that contained a particular prey type by the total number of stomachs with prey.

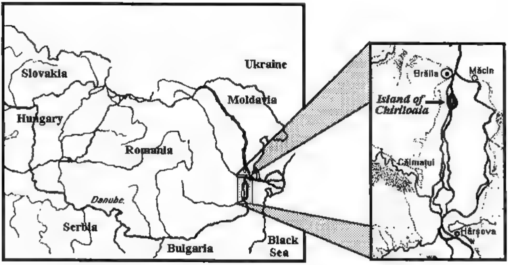


Fig. 1. – Location of the study site (island of Chiriloaia) in the lower Danube floodplain

The trophic diversity was estimated with Brillouin's index (*HB*) and evenness (*E*) (MAGURRAN, 1988):

$$HB = \frac{lnN!-\Sigma lnn_i}{N}, \text{ and}$$

$$E=HB/HB_{max},$$

where N is the total number of prey individuals and n_i is the number of individuals of prey type i.

The Berger-Parker (d) index of dominance was also used, as a measure of the degree of specialization:

$$d = \frac{n_i \max}{N},$$

where d varies between $1/N$ and 1. A value of d close to 1 indicates a high specialization in feeding, while a low value close to $1/N$ is characteristic of a generalist feeder.

The different prey resource states were compared with the relative numerical abundance in the environment and the selectivity in feeding was estimated using Manly's Alpha prey preference index (MANLY et al., 1972; CHESSON, 1978):

$$\alpha_i = \frac{n_i}{r_i} \times \frac{1}{\sum \frac{n_j}{r_j}},$$

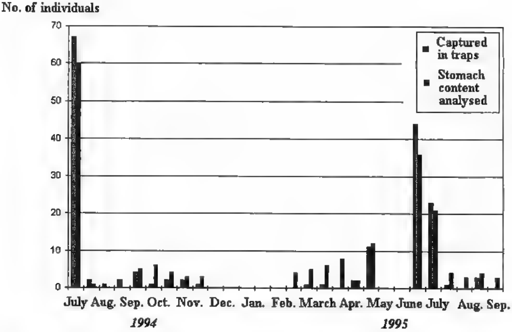


Fig. 2. – Numbers of individuals of *Pelobates fuscus* captured monthly in traps and numbers of stomach contents analyzed.

where n_i and n_j represent the abundance of prey taxa *i* and *j* in stomach contents, while r_i and r_j represent their abundance in the environment. If $\alpha_i > 1/T$, where *T* is the total number of prey categories, then the prey type *i* is considered preferred. Selectivity in feeding also was estimated according to Ivlev (1961):

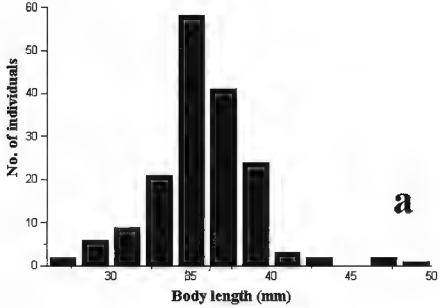
$$E = \frac{n_i - r_i}{n_i + r_i},$$

where *E* can vary between –1 and 1.

Results

The frequency of capture in traps and field observations indicated that the highest number of active spadefoot toads was observed when newly metamorphosed juveniles began migrating away from water (fig. 2). Increased activity was also observed during or after rain. Most of the animals studied were juveniles and subadults (fig. 3a), because they represented the largest part of the population (Cogălniceanu et al., 1997).

Each of 119 individuals of the 190 studied (62 %) contained at least one prey item in its stomach. The average number of prey items per stomach was 5.5, ranging between 1 and 17



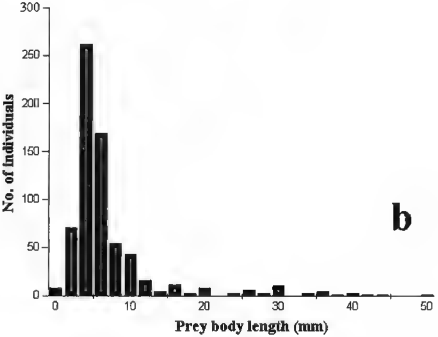


Fig. 3. – (a) Size distribution of the 190 individuals of *Pelobates fuscus* studied (b) Size distribution of the 664 prey items identified in stomach contents.

(fig. 4). A total of 664 invertebrates from 36 prey categories were identified from the stomach contents (tab. 1). The average number of individuals per prey category was 17 ± 3.7. The number of prey categories encountered increased with the number of stomachs analyzed, approaching the upper limit at 100 stomachs. Overall, the average number of prey categories per stomach was low (1.4 ± 0.08).

Most of the prey consumed (75 %) were small, with a body length between 2 and 6 mm (fig. 3b). The largest prey taxa belonged to four categories: Annelida, Diplopoda, Chilopoda and larvae of Lepidoptera. A significant positive correlation was found between toad body length and prey length ($r = 0.29$, $P < 0.001$, $n = 634$). Significant positive correlations were also found between toad body length and average, maximum and minimum prey size (fig. 5). The lower prey size limit for *Pelobates fuscus* is around 0.8-1 mm, while the upper limit seems constrained only by the width of the mouth.

Insects represented more than half (58.8 %) of the prey categories consumed, with ants (Formicidae) and beetles (Coleoptera) being dominant. These two insect taxa together with snails (Pulmonata) comprised half (50.6 %) of the prey categories consumed. The remaining taxa represented less than 10 % each (tab. 1). Spadefoot toads had a broad trophic niche, with little specialization in feeding. The mean number of individuals per stomach was greater than 2.0 for snails (Pulmonata), ants (Formicidae) and fly larvae (Muscidae). These three prey taxa either are slow moving or are distributed locally in the environment, indicating that *Pelobates fuscus* is actively foraging on them. Prey diversity was high, with a Brillouin diversity index of 2.83, and evenness of 0.83. The Berger-Parker index of dominance has a low value ($d = 0.18$), with the dominant prey taxa being ants (Formicidae).

Pitfall traps are commonly used for capturing cursorial invertebrates and in their action they may be regarded as analogous to a sit-and-wait predator (Cornish et al , 1995). Catch size is dependent on both abundance and activity (Thiele, 1977) and can correlate well with prey encounter rate for spadefoot toads. A total of 55,364 invertebrates from 53 taxa were captured with pitfall traps and identified during the study period. The relative abundance of prey types in stomach contents and in the environment and the values of the two selectivity indexes are presented in tab. 2. The analysis of the relative abundance of the different taxa from the environment showed that five categories represented more than 70 % of the identified prey taxa. These were: Crustacea, Acari, Collembola, Formicidae and Carabidae. Seventeen taxa present only occasionally in the pitfall trap captures were not found amongst the food of spadefoot toads.

The frequency of occurrence of two of the dominant taxa (Hymenoptera and Coleoptera) correlated well with their relative abundance in the environment. For Gastropoda, the estimated abundance from trap captures is biased, due to the low mobility of this group. The most abundant taxon in traps is Collembola, a group of tiny, soil dwelling insects.

The relative abundance of the different prey taxa in the environment and in the stomach contents of *Pelobates fuscus* is positively correlated ($r = 0.71$, $P < 10^{-4}$) (fig. 6). There is also a positive correlation between the relative abundance in the environment and the frequency of occurrence ($r = 0.69$, $P < 10^{-4}$).

Tab. 1 - Prey taxa removed from stomachs of 119 spadefoot toads. *n*: number of individuals per taxon. A_n: percent of the total number of invertebrates accounted for by the particular prey type. FO: frequency of occurrence, i.e. number of stomachs containing at least one prey item, divided by the total number of stomachs with prey (119), multiplied by 100. ANIS: average number of individuals/stomach.

Prey taxa	*n*	A_n (%)	FO	ANIS
Platyhelminthes	1	0.15	0.84	1.00
Annelida, Oligochaeta	5	0.75	4.20	1.00
Crustacea, Isopoda, Oniscoidea	53	7.98	24.36	1.82
Gastropoda, Pulmonata	127	19.12	52.10	2.04
Diplopoda, Juliformia	36	5.42	23.52	1.28
Chilopoda, Lithobiomorpha	8	1.20	4.20	1.60
Arachnida, Acari	12	1.80	8.40	1.20
Arachnida, Araneae	29	4.36	19.32	1.26
Arachnida, Opilionidae	2	0.30	1.68	1.00
Insecta, adults undetermined	7	1.05	5.04	1.16
Insecta, larvae undetermined	14	2.10	10.08	1.16
Collembola, undetermined	17	2.56	7.56	1.88
Collembola, Entomobryidae	9	1.35	4.20	1.80
Collembola, Sminthuridae	21	3.16	9.24	1.90
Total Collembola	47	7.07	21.00	1.88
Dermaptera, *Forficula* sp	4	0.60	3.36	1.00
Hemiptera	3	0.45	2.52	1.00
Lepidoptera, larvae	22	3.31	14.28	1.29
Orthoptera	3	0.45	2.52	1.00
Homoptera, undetermined	4	0.60	3.36	1.00
Homoptera, Aphididae	17	2.56	7.56	1.88
Homoptera, Cicadidae	12	1.80	9.24	1.09
Total Homoptera	33	4.96	20.16	1.37
Hymenoptera, undetermined	16	2.40	10.08	1.33
Hymenoptera, Formicidae	124	18.67	25.12	2.48
Total Hymenoptera	140	21.08	52.10	2.25
Diptera, adults undetermined	9	1.35	5.04	1.50
Diptera, larvae undetermined	6	0.90	3.36	1.50
Diptera, Muscidae, adults	4	0.60	3.36	1.00
Diptera, Muscidae, larvae	7	1.05	1.68	3.50
Diptera, Culicidae	7	1.05	4.20	1.40
Total Diptera	33	4.96	17.64	1.57
Coleoptera, undetermined	29	4.36	19.38	1.25
Coleoptera, Carabidae, adults	26	3.91	15.12	1.44
Coleoptera, Carabidae, larvae	6	0.90	4.20	1.20
Coleoptera, Chrysomelidae	6	0.90	4.20	1.20
Coleoptera, Curculionidae	6	0.90	5.04	1.00
Coleoptera, Coccinellidae	2	0.30	1.68	1.00
Coleoptera, Elateridae	3	0.45	1.68	1.50
Coleoptera, Staphylinidae	6	0.90	5.04	1.00
Coleoptera, Sylphidae	1	0.15	0.84	1.00
Total Coleoptera	85	12.80	57.14	1.25

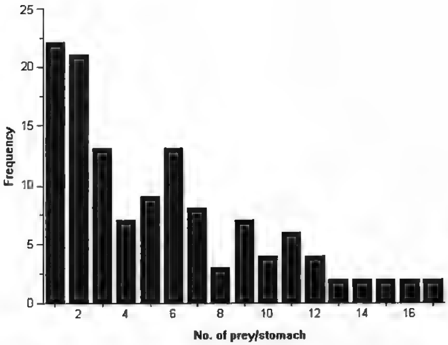


Fig. 4. Frequency distribution of the number of prey found per stomach in the 119 individuals of *Pelobates fuscus* with at least one prey item in their stomach.

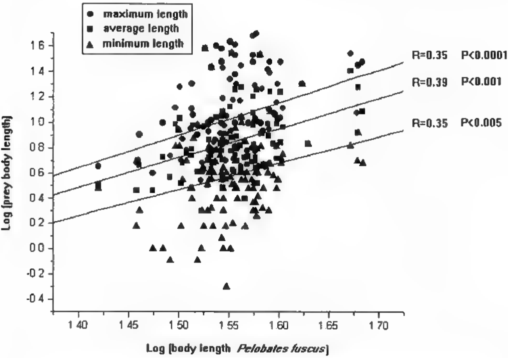


Fig. 5. – Relationships between spadefoot toad body length and average, maximum and minimum prey body length.

Tab. 2. - Prey abundance in the stomach contents (sc) of spadefoot toads and in the environment (env), expressed as number of individuals (n) and percentage of the total number (A). Also shown are the values for the two measures of prey preference. Manly's Alpha index (α_i) and Ivlev's index (E_i). * Preferred prey taxa ($\alpha_i > 0.035$), ** Preferred prey taxa ($E_i > 0.5$); *** Avoided prey taxa ($E_i < -0.5$).

Prey taxa	n_{sc}	A_{sc} (%)	n_{env}	A_{env} (%)	α_i	E_i
Annelida, Oligochaeta	5	0.77	28	0.05	0.1054*	0.87**
Crustacea, Oniscoidaea	53	8.22	6589	11.90	0.0047	- 0.18
Gastropoda, Pulmonata	127	19.72	1363	2.46	0.0550*	0.77**
Diplopoda, Juliformia	36	5.59	1799	3.24	0.0118	0.26
Chilopoda, Lithobiomorpha	8	1.24	495	0.89	0.0095	0.16
Arachnida, Acari	12	1.86	4837	8.73	0.0014	- 0.64***
Arachnida, Araneae	29	4.50	3726	6.73	0.0045	0.19
Arachnida, Opilionidae	2	0.31	315	0.56	0.0037	- 0.29
Collembola	47	7.29	10543	19.04	0.0026	- 0.44
Dermaptera	4	0.62	11	0.01	0.2146*	0.93**
Hemiptera	3	0.46	369	0.66	0.0048	- 0.17
Lepidoptera, larvae	22	3.41	148	0.26	0.0877*	0.85**
Orthoptera	3	0.46	122	0.22	0.0145	0.35
Homoptera, Aphididae	17	2.63	520	0.93	0.0193	0.47
Homoptera, Cicadidae	12	1.86	310	0.55	0.0228	0.53**
Other Homoptera	33	5.12	830	1.49	0.0234	0.54**
Hymenoptera	16	2.48	1014	1.83	0.0093	0.15
Hymenoptera, Formicidae	124	19.25	11354	20.50	0.0064	- 0.03
Diptera	33	5.12	1663	3.00	0.0117	0.26
Coleoptera, larvae	7	1.08	2002	3.61	0.0020	- 0.53***
Coleoptera, Carabidae	26	4.03	6349	11.46	0.0024	- 0.47
Coleoptera, Chrysomelidae	6	0.93	76	0.13	0.0466*	0.74**
Coleoptera, Curculionidae	6	0.93	52	0.09	0.0681*	0.81**
Coleoptera, Coccinellidae	2	0.31	7	0.01	0.1686*	0.92**
Coleoptera, Elateridae	3	0.46	22	0.03	0.0805*	0.84**
Coleoptera, Staphylinidae	6	0.93	396	0.71	0.0089	0.13
Coleoptera, Sylphidae	1	0.15	341	0.61	0.0017	- 0.59***

DISCUSSION

The feeding habits of any species lies somewhere between the two extremes of foraging patterns: sit-and-wait and active-foraging. The population of *Pelobates fuscus* studied is nearer the active foraging mode. This can be inferred from the large numbers of prey types with relative low mobility (Gastropoda, Crustacea) and isolated distributions in the environment (Formicidae and larvae of Muscidae) consumed. Individuals in the studied population of *Pelobates fuscus* appear to be opportunistic feeders with a wide trophic niche and a lack of selectivity in feeding.

Few papers present data on the food and feeding habits of spadefoot toads. Most of the existing studies are based on the analysis of a small number of animals. For example, GUTOWSKI & KRZYSZTOFIAK (1988) analyzed the stomach contents of only two animals, and

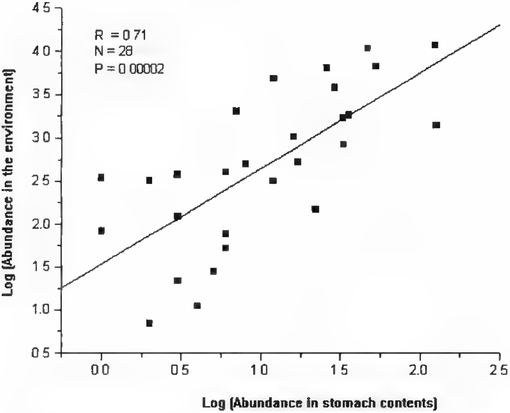


Fig. 6. Correlation between prey abundance in the environment and abundance in stomach contents.

other authors have ignored small prey taxa, like Collembola and Acari (Medvedev, 1974, Sczerbak & Sczerban, 1980). Contrary to the present results, Kuzmin (1995) reported that spadefoot toads preferred crawling invertebrates while ants are consumed less frequently. Among Coleoptera, this author stated that beetles belonging to the families Carabidae and Tenebrionidae are preferred, while Juszczyk (1974) stated that spadefoot toads prefer Carabidae, Elateridae and Staphylinidae.

Medvedev (1974) analyzed the stomach contents of 25 spadefoot toads and identified 100 prey items, of which 9 % were spiders and 81 % were Coleoptera. Ants were completely lacking from the diet, although they were present in the food of the other amphibian species from the same location. The Berger-Parker index was 0.23 when the most abundant carabid species (*Harpalus distinguendus*) was considered, and 0.64 when all carabids were pooled. It is possible that because smaller animals were not counted these results were skewed. Sczerbak & Sczerban (1980) identified 48 prey items in the stomach contents of 25 spadefoot toads. The most abundant taxon was also Carabidae (Berger-Parker index d = 0.23). They also reported the presence of several flying insects like Noctuidae (12.6 %) and Ichneumonidae

(4.2 %). Ants were represented by only two individuals (4.2 %). The small proportion of ants reported by these authors suggests that, although generally abundant in the environment, ants are usually avoided. In the present study, *Pelobates fuscus* inhabited a highly variable, unpredictable environment, and ants were consumed possibly because of a limited choice of other prey during floods. A study of the feeding ecology of two genera of North American spadefoot toads (*Scaphiopus* and *Spea*) showed that these are generalized arthropod predators, with ants representing a significant component of their diet (PUNZO, 1991).

The striking variations in food profiles of spadefoot toads reported by different authors may be explained by differences in prey availability and may support the idea that *Pelobates fuscus* is a generalist feeder. No further comparisons are possible due to the lack of information on prey availability and the fact that prey taxa identification was done at different taxonomic levels.

Many papers are devoted to the study of prey availability in relation to selective predation (CHESSON, 1978; GRIFFITHS, 1975; HURTUBIA, 1973; SMITH, 1982; WINEMILLER & PIANKA, 1990). Of the various approaches proposed, two of the simplest measures of prey preference (Manly's Alpha index and Ivlev's index) were tested in the present study (tab. 2).

Manly's Alpha index is not very useful because the preferred taxa, Annelida, Gastropoda, and Lepidoptera larvae, have low mobility and a low probability of capture in traps, so their relative abundance in the environment is probably higher than estimated. Another taxon that appeared to be preferred (Dermaptera) yielded low numbers of individuals in the stomach content analysis and in the trap captures, so no valid conclusion can be drawn. The same caution must be taken when considering the various preferred families of Coleoptera. The selectivities computed using this index tended to give counterintuitive weight to some insignificant taxa. Therefore, no definite conclusions about prey preference can be drawn from using this index.

Ivlev's index measures not only the preference for a prey type but also the lack of preference. Positive values indicate preference while negative values suggest avoidance of the prey. A threshold of $\pm$ 0.5 was considered, indicating the preference (> 0.5) or avoidance (< – 0.5) for a particular prey taxon. Only three prey taxa were avoided (Acari, Coleoptera larvae and Sylphidae), with E_i values smaller than – 0.5. Acari and Coleoptera larvae have low mobility and live mainly in the litter, so they are consumed only accidentally. Sylphidae are present in very low numbers and are active mainly during daylight, contrary to spadefoot toads that feed only during the night.

Ten taxa had positive values greater than 0.5, suggesting a preference in prey choice. Of these, eight were also considered preferred by the Manly's Alpha index. The other two taxa (Cicadidae and unidentified Homoptera) are mainly plant dwelling insects and are seldom caught in traps. Although Ivlev's index discriminates better in analyzing selectivity in feeding, most of the results are biased by the method of estimating relative abundance in the environment of the particular taxa.

A high number of juveniles, up to 96 % of the entire population, was also recorded in a *Pelobates fuscus* population from an artificial island surrounded by the Danube, near Vienna (JEHLE et al., 1995). The large number of empty stomachs encountered, together with the large stomach volume of this species, suggests that feeding varies in time depending on weather conditions, rain and air temperature. During the study period, spadefoot toads were active and feeding during most of the year, except for the three-month period of frost from December 1994 to February 1995 (fig. 2). According to Kuzmin (1995), spadefoot toads use active search foraging tactics, searching up to 200 m^2 each night.

The slight positive correlation between the size of spadefoot toads and prey size, together with the diversity of prey categories encountered, suggested that larger animals eat larger prey, which is consistent with Griffiths's (1975) predictions that predators can eat only a certain size range of prey organisms. The low occurrence of Collembola in food is possibly due to their small dimensions that make them difficult to locate and not energetically rewarding to pursue. Boomsa & Arntzen (1985) found that the proportion of Collembola in the stomach contents in a population of *Bufo calamita* varied sharply during the year, their relative contribution being negatively correlated with the size of the toad. However, this does not limit the breadth of the trophic niche, and larger animals consumed a higher diversity of food. Partitioning of resources between size classes is thus possible, as previously observed by Joly & Giacoma (1992).

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